BASIC SIX SIGMA CONCEPTS

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OPERATING EXCELLENCE MEANS LEAN PROCESSES WORKING AT SIX SIGMA QUALITY LEVELS

MIKE JOYCE
LOCKHEED-MARTIN

GE’s Definition of Six Sigma

Six Sigma is the disciplined methodology of defining, measuring, analyzing, improving and controlling the quality in every one of the Company’s products, processes and transactions-with the ultimate goal of virtually eliminating all defects.

“This is the most important initiative this Company has ever undertaken. (It) will fundamentally change our Company forever”.

John F. Welch, JR.

Who’s Using Six Sigma?

Motorola/ Allied Signal/ General Electric/ Sony/ Ford/ Honda/ General Motors

Maytag/ Raytheon/ Texas Instruments/ Canon/ Hitachi/ Polaroid/ Nokia

American Express/ Toshiba/ DuPont/ FedEx/ Shimano

Bombardier/Lockheed-Martin/ABBGroup/Northrop-Grumman

Black & Decker/Dow Chemical/Johnson & Johnson/Kodak/Navistar/

Why Did it Start? **BUSINESS SURVIVAL !**

- Late 70's vs Motorola TVs; "Our quality stinks…"/ Japanese buyout
- 1984: Bill Smith of Motorola

  - system complexity

  - process variability and drift

  - the effect of factory rework on system reliability

- 1985: Mikel Harry of Motorola - use of statistics to improve quality
- 1990: * Motorola Bandit Pager

  How do we get a "true" 99% "first-pass" yield of pagers, where each pager has 2000 components ?

- Rolled Yield Throughput:

  we need $Y^{2000} = 0.99$

Defining Six Sigma

• A business initiative that employs engineering and statistics:

- uses financial measures to select projects

- uses financial measures to determine success

- attacks variation in products, processes and services

- has the goals of increased profitability and ROI

- requires leadership, training, infrastructure, tools and methods

• 99.9999998% Best Case “Quality”

• 99.99966% Worst Case “Quality”

• 2 ppb ≤ Defects ≤ 3.4 ppm

• Cp = 2.0

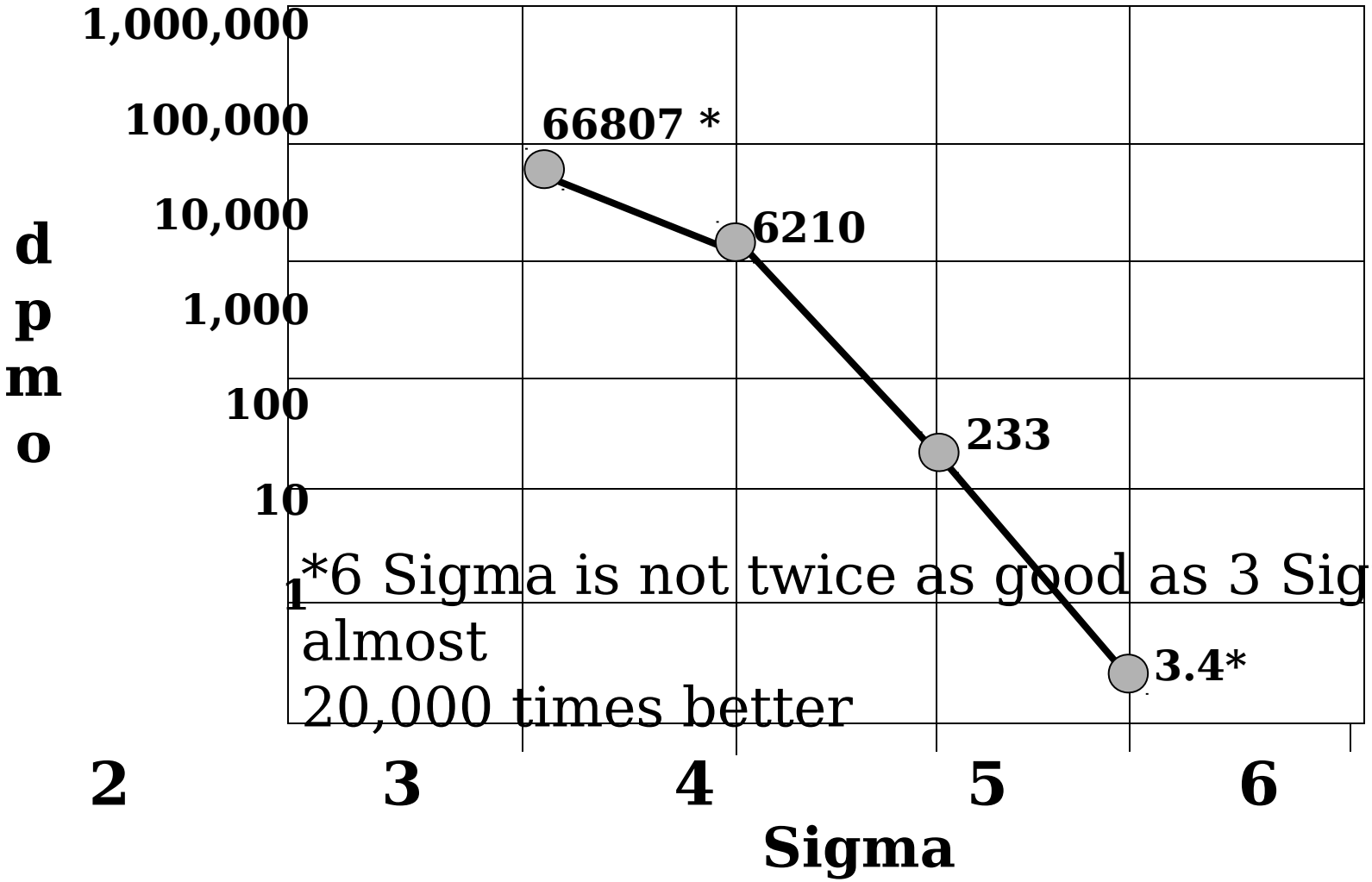
•Cpk = 1.5

• Builds on the works of Deming, Juran, Taguchi and

SIGMA

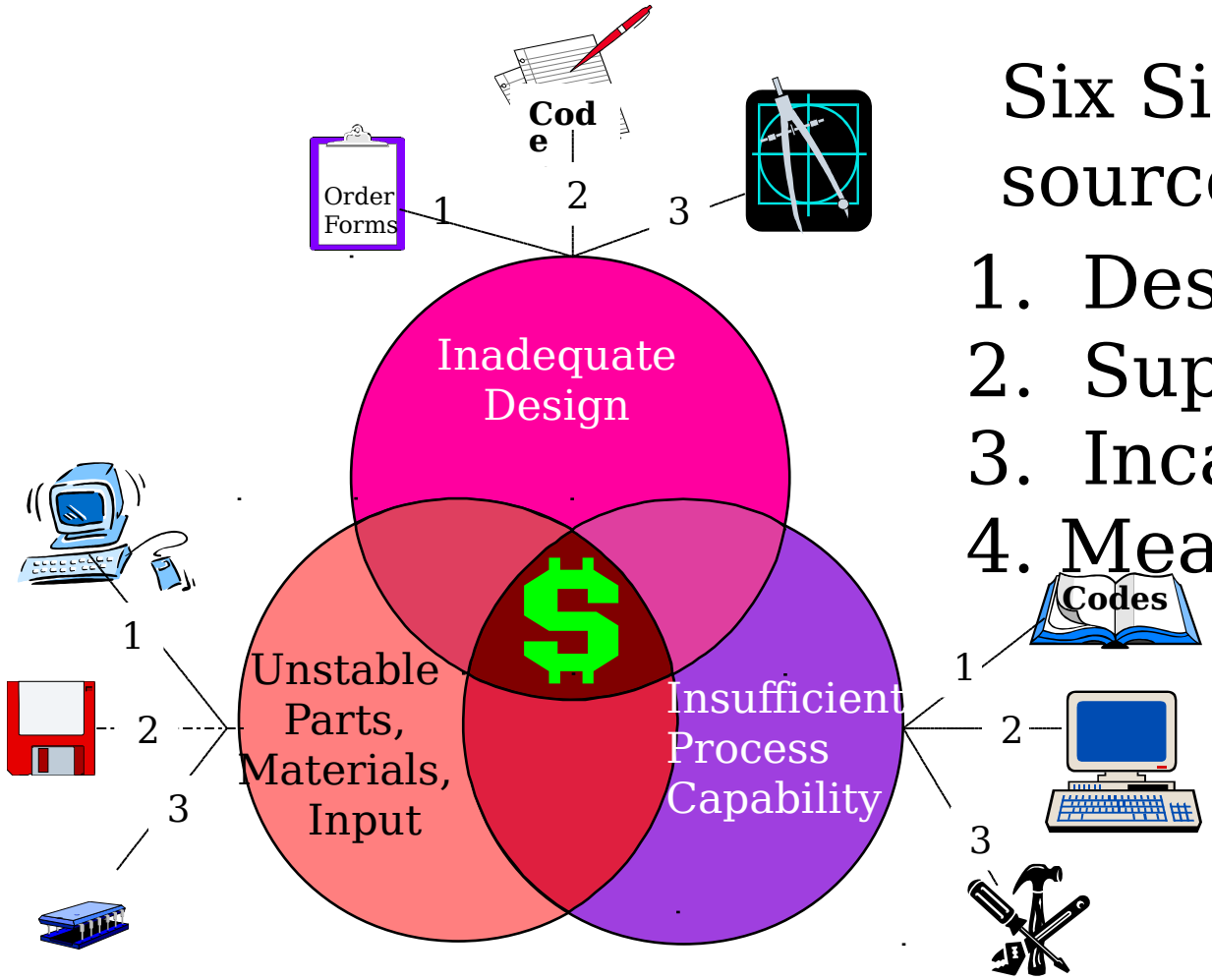
		DPMO
• IRS Phone-in tax advice	2.2σ	241,964
• Restaurant bills, doctor's bills, prescription writing, and payroll processing	2.9σ	80,757
• Average manufacturing Company	3.0σ	66,807
• Airline baggage handling	3.2σ	44,565
• Best-in-class companies	5.7σ	13
• U.S. Navy aircraft accidents	5.7σ	13
• Watch error of 2 seconds in 31 years	6σ	3.4
• Airline Industry Fatality rate	6.2σ	0.43

DPMO to Sigma Relationship



*6 Sigma is not twice as good as 3 Sigma, it is almost
20,000 times better

What is Six Sigma?



Region of Six Sigma Synergy

Six Sigma attacks sources of variability i

1. Design
2. Suppliers/Vendors
3. Incapable processes
4. Measurement

Six Sigma Tools

- **Applied Statistics**

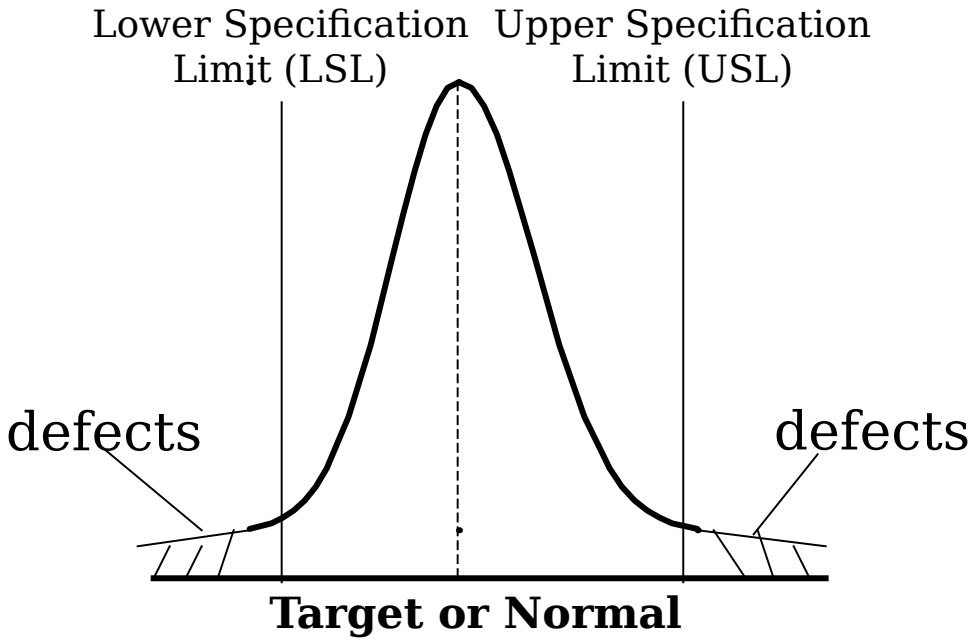
SPC/ DOE/ ANOVA/ Regression/ Confidence Testing

- **Basic Analytical Tools**
- **Process Capability & Process Performance**
- **Measurement Systems Analysis(Gauge Repeatability & Reproducibility) One of the first tech issues to be checked ! 20% -25% ?**
- **Reliability Engineering**

Variation Creates Defects

Six Sigma is all about Variation

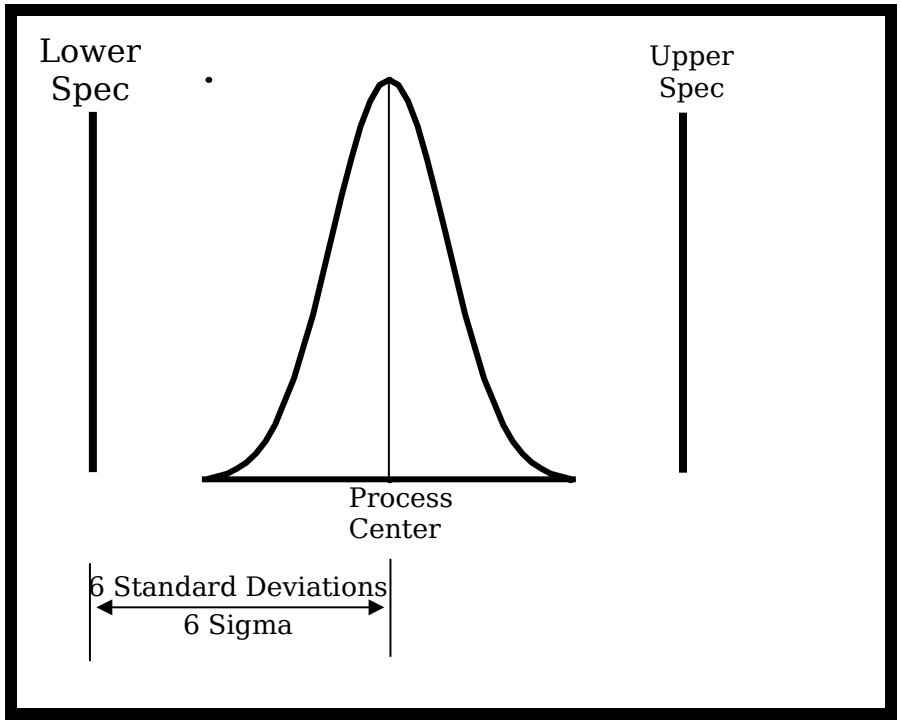
Process/Product performance, i.e., variation from the target value as depicted as a normal distribution



What is Six Sigma?

Variation is the Enemy

- Sigma refers to standard deviation, measure of variation.
  - **Six Sigma refers to a process having six standard deviations (short term) between the process mean and the nearest specification limit.**



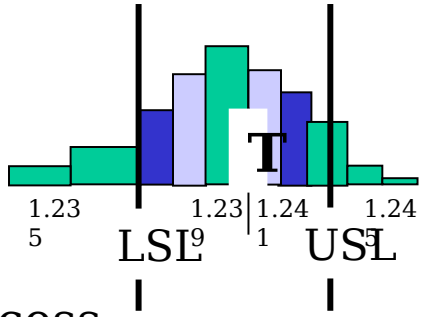
Continuously……..

- Improve yields
- Eliminate defects
- Reduce the cost of poor quality and
- Reduce cycle time

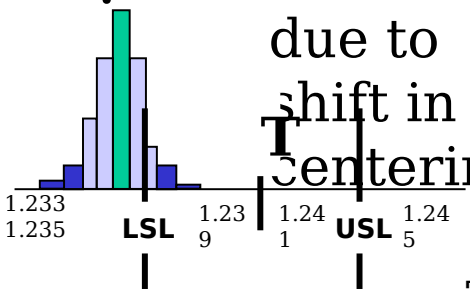
…..for each process

The Basics

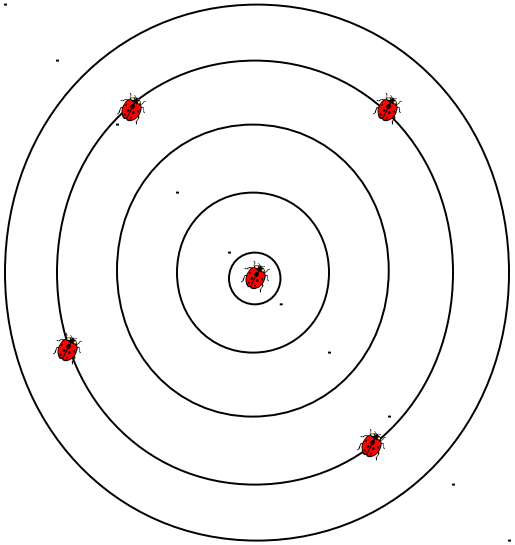
We desire a centered process with little variability

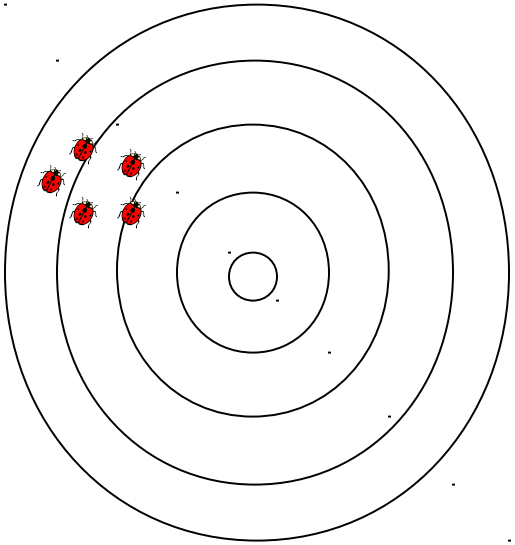


Increase in nonconformance due to shift in process centering



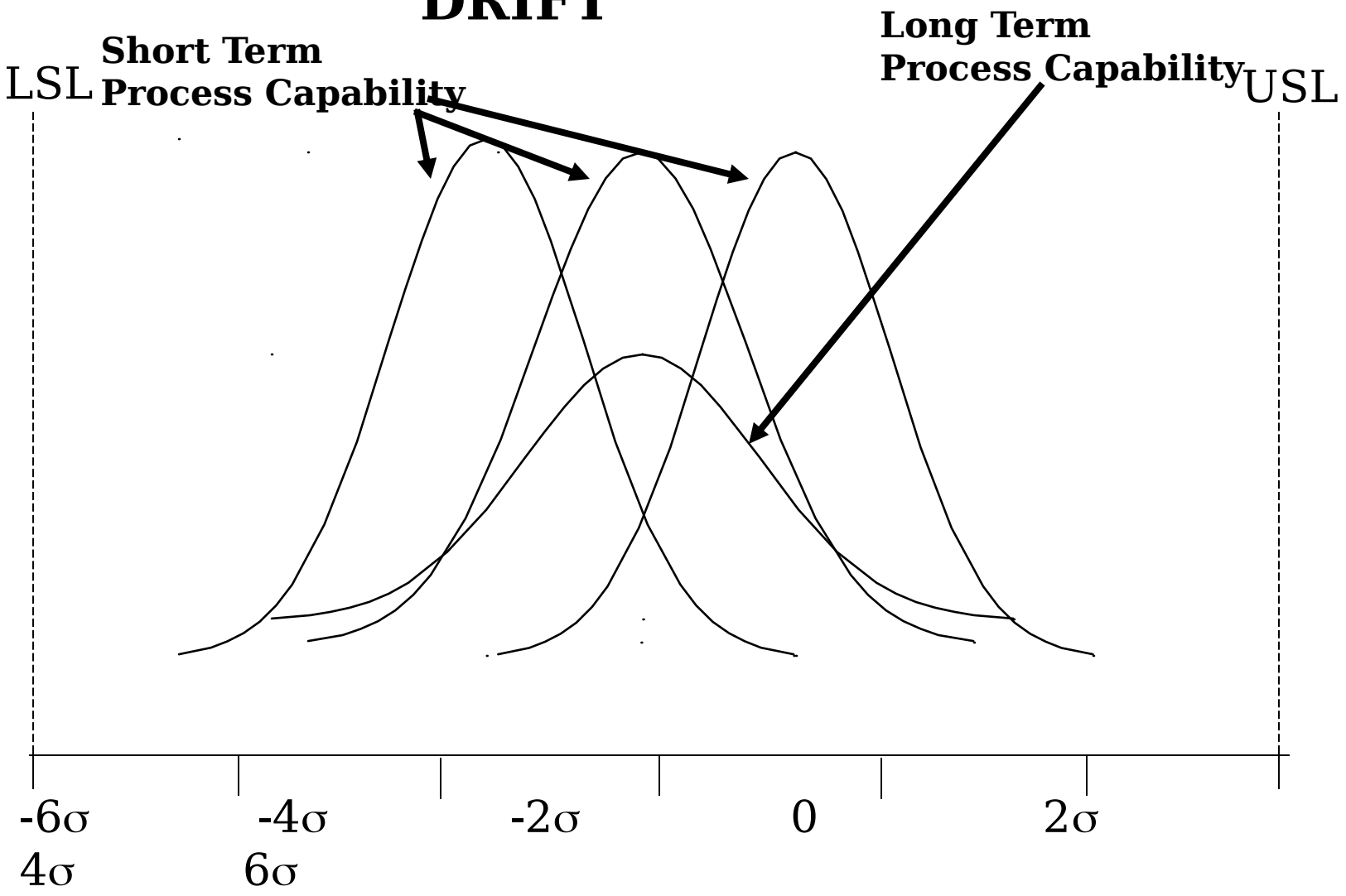
The process width is independent of the design width.





The process center is independent of the design center.

THE EFFECT OF PROCESS DRIFT



Defects Before and After Process Drift

Sigma Level	W/O Shift	With 1.5 Shift*
1	317,400 ppm	697,700 ppm
2	45,400 ppm	308,537 ppm
3	2,700 ppm	66,807 ppm
4	63 ppm	6,220 ppm
5	0.57 ppm	233 ppm
6	0.002 ppm	3.4 ppm

* The 1.5σ shift provide a more realistic view of a process' long-term capability

Breakthrough Technologies for Success

Measure - Analyze - Improve - Control (MAIC)

M

Phase 1

1. Select CTQ Characteristics
2. Define Performance Standards
3. Validate Measurement System

A

Phase 2

4. Establish Product Capability
5. Define Performance Objectives
6. Identify Variation Sources

I

Phase 3

7. Screen Potential Causes
8. Discover Variable Relationship
9. Establish Operating Tolerances

C

Phase 4

10. Validate Measurement System
11. Determine Process Capability
12. Implement Process Controls

Rolled Throughput Yield (RTY) takes into account the
hidden operations: defects and rework.

RTY is process oriented - not finished product oriented. It measures defects in CTQ characteristics in the entire process, not defective units at the end of the line.

ROLLED THROUGHPUT YIELD (Y_{RT})

(The probability of a true long-term "first pass yield")

Receive parts

RAW MAT

95.5% Yield Following Receiving Inspection (Y_{TP})

1

97% Machining Operations Yield (Y_{TP})

2

94.4% Finishing Operations Yield (Y_{TP})

3

*Waste

*Waste

*Waste

OUT

= 87.45 %

Right first time

131.000 PPM defective

Y_{RT} = .955 x .97 x .944

= 87.45%

*Wasted resources (time, money, etc)

References

The Six Sigma Way, Pande, Neuman and Cavanagh. McGraw-Hill, 2000.

Implementing Six Sigma, Breyfogle. John Wiley & Son, 1999.

Six Sigma, Harry and Schroeder. Doubleday, 2000.

END

REFERENCES ATTACHED

Definitions

• **Variation**: amount, rate, extent or degree of change; the amount to which a process outcome differs from a desired target. Variation that results in a process exceeding specifications limits creates defects.

• **Sigma**: the Greek letter used to describe the standard deviation of data; a measure of variation of a normal distribution; a measure of consistency of a process; measures the variation of data; one standard deviation is represented by σ.

• **CTQ**: “Critical to Quality”; customer wants clearly defined as an explicit requirement; an element of a design or a characteristic of a part that is essential to quality in the eyes of the customer. Six Sigma attacks CTQ variation.

• **Defect**: Anything that blocks or inhibits a process or service; any instance or event in which the product or process fails to meet a customer requirement; a failure to meet an imposed requirement on a single quality characteristic or a single instance of nonconformance to

Process Capability Indices

$$C_p = \frac{\text{Specification Width}}{\text{ST Process Width}} = \frac{USL - LSL}{6\sigma_{ST}}$$

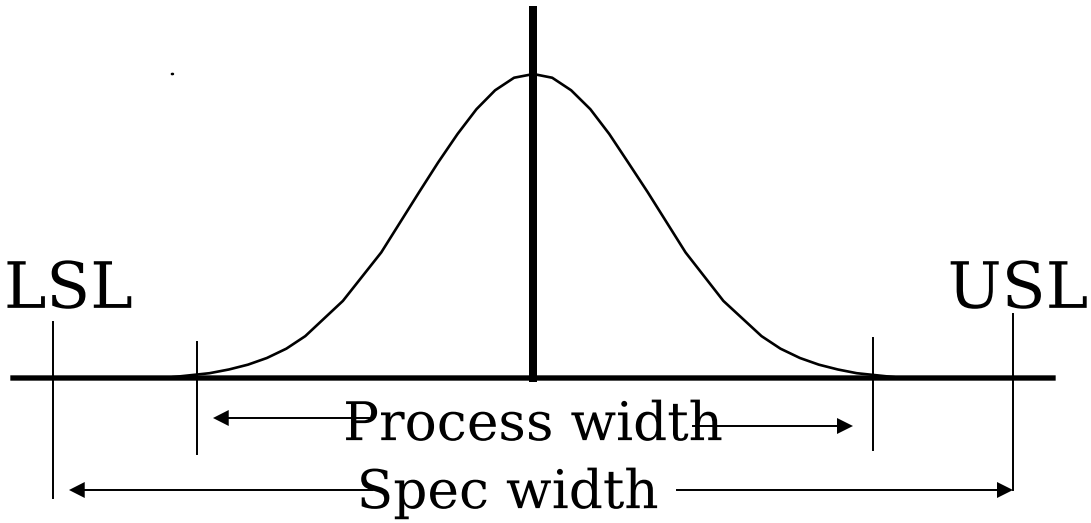
$$C_{pk} = \text{Lesser of: } \frac{USL - \bar{X}}{3\sigma_{ST}} \text{ or } \frac{\bar{X} - LSL}{3\sigma_{ST}}$$

Control charts tell us when a process is in statistical control,
but not whether the process output meets specification.

Process Capability is a measure of the ability of the process to produce product

POTENTIAL CAPABILITY (Centered Process)

$$C_p = \frac{\text{Specification Width}}{\text{Short Term Process Width}} = \frac{\text{USL - LSL}}{6\sigma_{ST}}$$

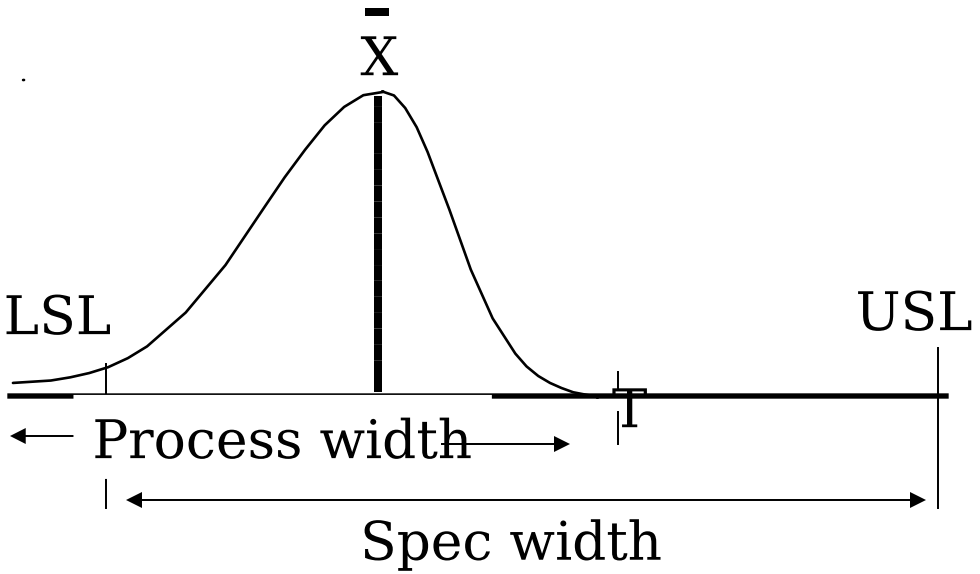


ST = Short Term

Ex: 6 sigma processes have an index of 2.0

Demonstrated Capability

$$C_{pk} = \text{Lesser of } \frac{USL - \bar{\bar{X}}}{3\sigma_{ST}} \text{ or } \frac{\bar{\bar{X}} - LSL}{3\sigma_{ST}}$$



C_{pk} = Demonstrated capability
(Process not-centered)

EX : 6σ processes have a C_{pk} of 1.5

Is 6σ Software Good Enough?

Does 6σ apply to software?

Motorola says it does.

SEI Software Maturity Model Level / Sigma Level

Level 3	5.8σ
Level 4	6.0σ
Level 5 (Space Shuttle)	6.3σ

Is 6σ software good enough?

Not if the software is used in medical equipment, aircraft flight control, nuclear power plant control systems or my credit card.